Spectral Processing of Point-sampled Geometry
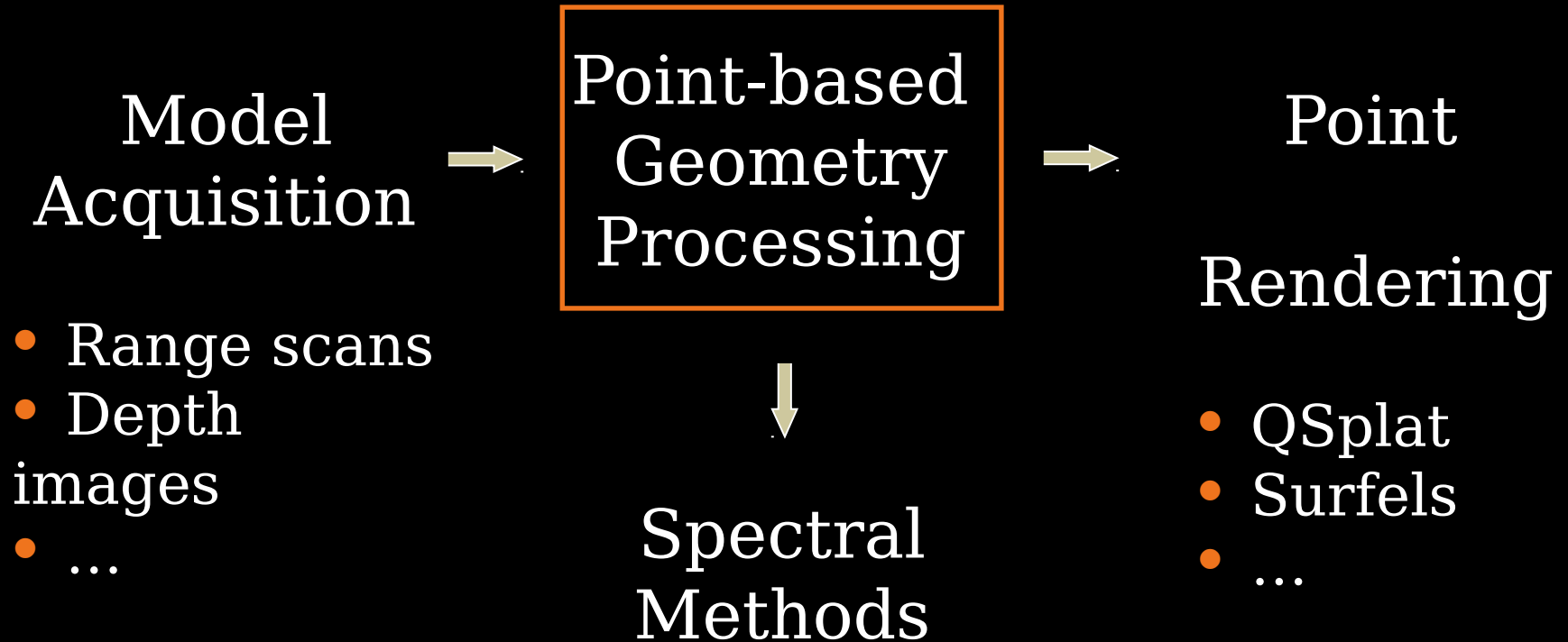
Mark Pauly **Markus Gross**

ETH Zürich

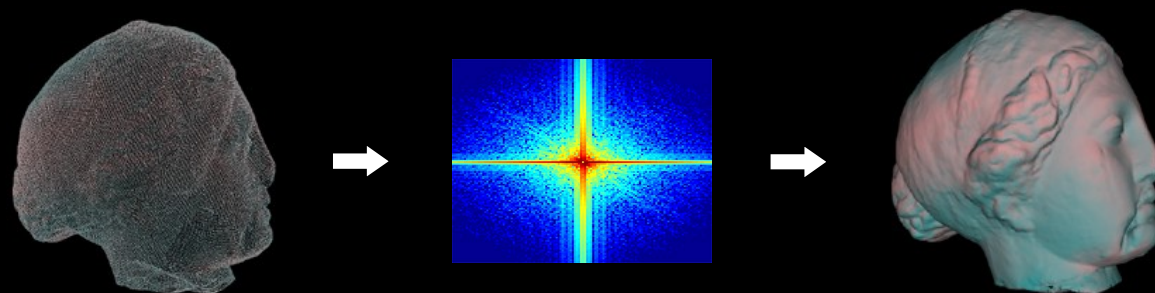computer
graphics
lab

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Outline

- Introduction

- Spectral processing pipeline

- Results

- Conclusions

Introduction

Model
Acquisition → Point-based
Geometry
Processing → Point

Rendering

- Range scans
- Depth
images
- …

Spectral
Methods

- QSplat
- Surfels
- …

Spectral Transform

- Extend Fourier transform to 2-manifold surfaces

⇨ Spectral representation of point-based objects

⇨ Powerful methods for digital geometry processing
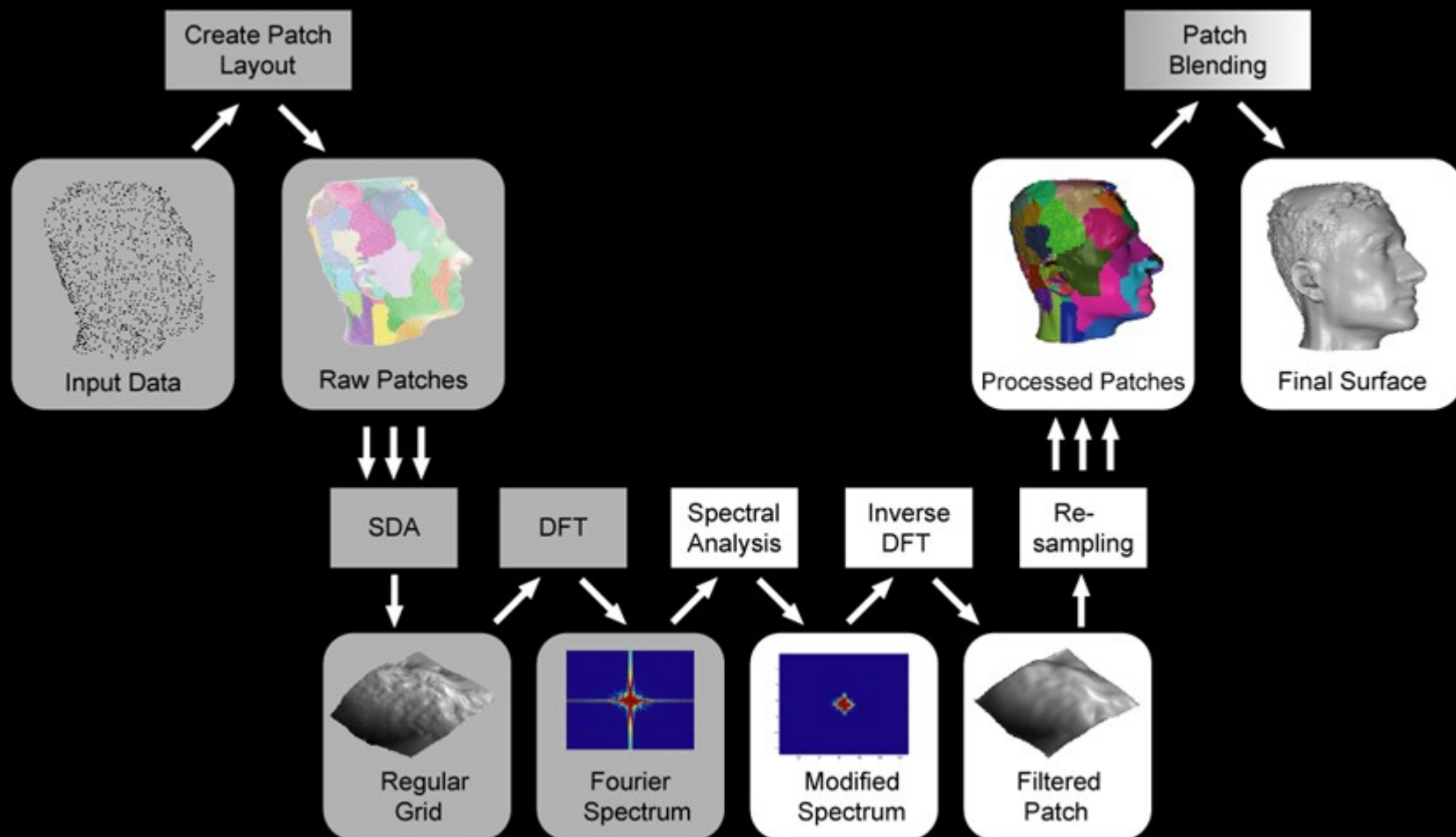
Applications

- Spectral filtering:
  - Noise removal
  - Microstructure analysis
  - Enhancement

- Adaptive resampling:
  - Complexity reduction
  - Continuous LOD

Fourier Transform

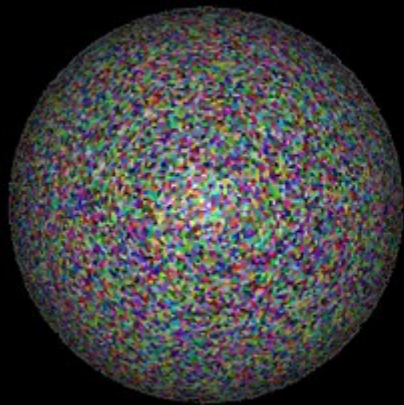$$X_n = \sum_{k=1}^{N} x_k e^{-j2\pi \frac{nk}{N}}$$

- Benefits:
  - Sound concept of frequency
  - Extensive theory
  - Fast algorithms

- Limitations:
  - Euclidean domain, global parameterization
  - Regular sampling
  - Lack of local control
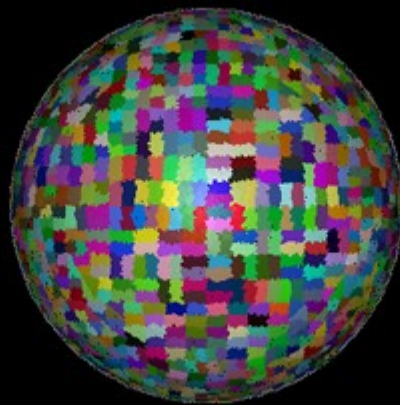
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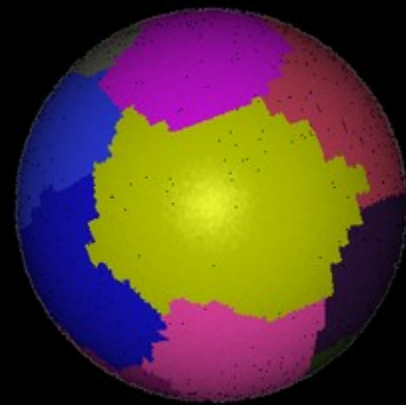AND DIGITAL IMAGES

Overview

Patch Layout Generation
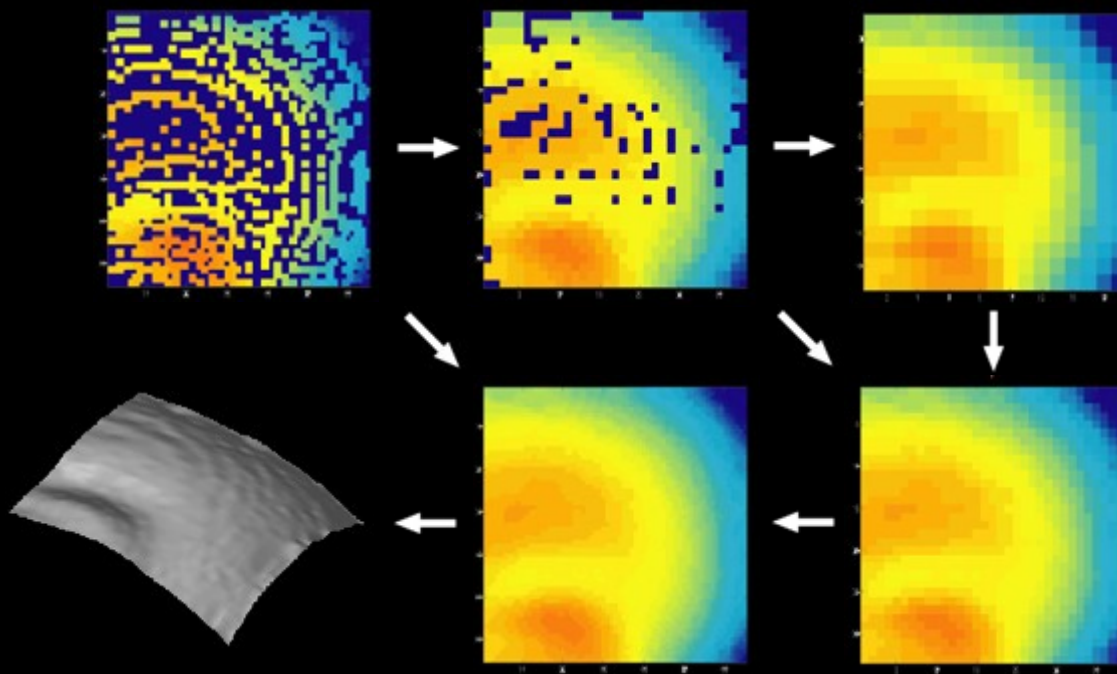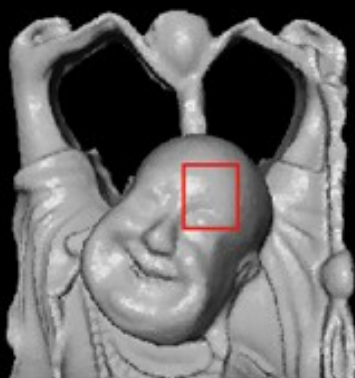
Clustering ⇨ Optimization

Samples ⇨ Clusters ⇨ Patches

Patch Merging Optimization

- Iterative, local optimization method

- Quality metric:

⇨ patch Size

⇨ curvature

⇨ patch boundary

⇨ spring energy regularization

Scattered Data Approximation

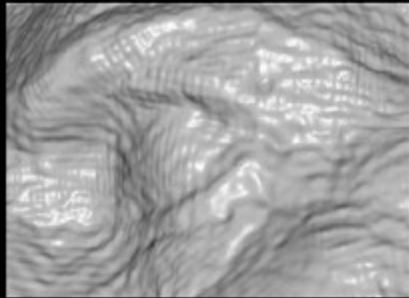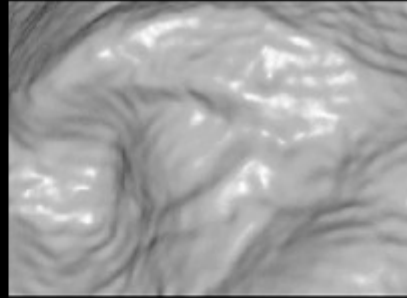## Hierarchical Push-Pull Filter:

Spectral Analysis

- 2D Discrete Fourier Transform (DFT)
  ⇨ Direct manipulation of spectral coefficients

- Filtering as convolution:

  ⇨ Convolution: $O(N^2)$ ⇨ Multiplication: $O(N)$
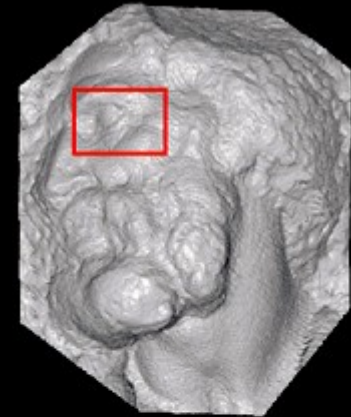
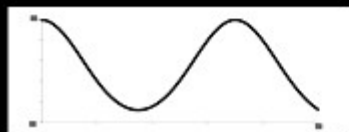- Inverse Fourier Transform
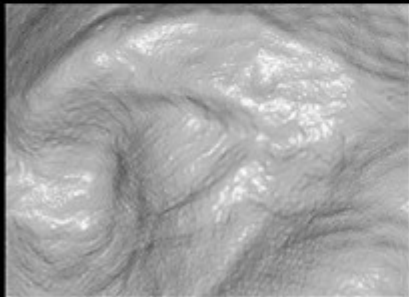 ⇨ Filtered patch surface

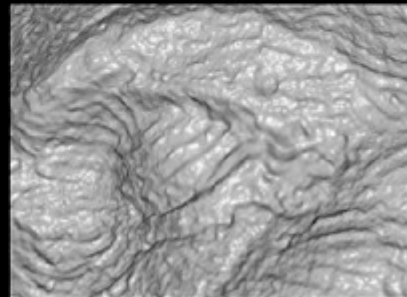# Spectral Analysis

Ideal low-pass
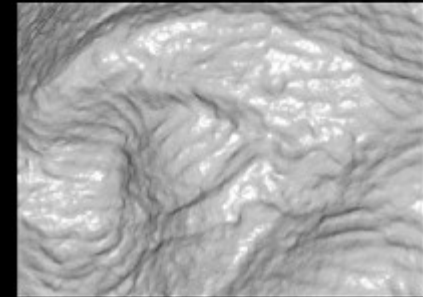
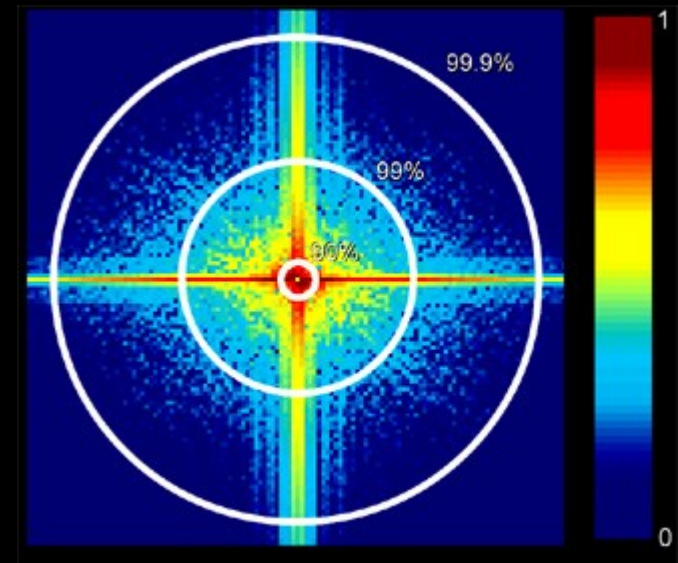

Gaussian low-pass

Original
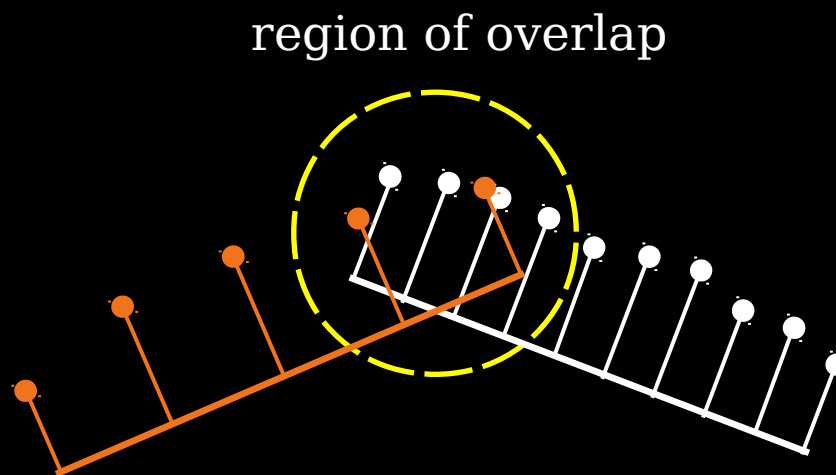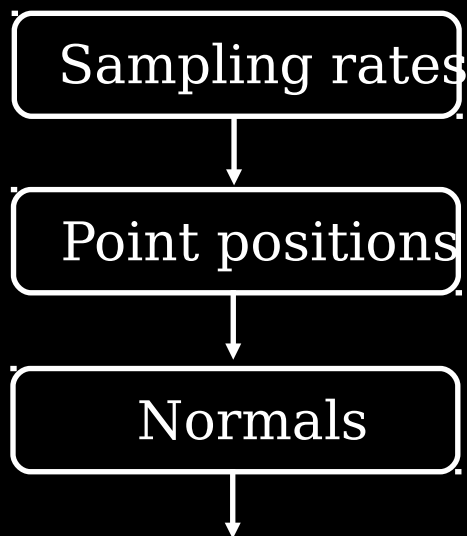

Band-stop

Enhancement

Resampling

- Low-pass filtering
  - ⇨ Band-limitation

- Regular Resampling
  - ⇨ Optimal sampling rate   (Sampling Theorem)
  - ⇨ Error control (Parseval's Theorem)
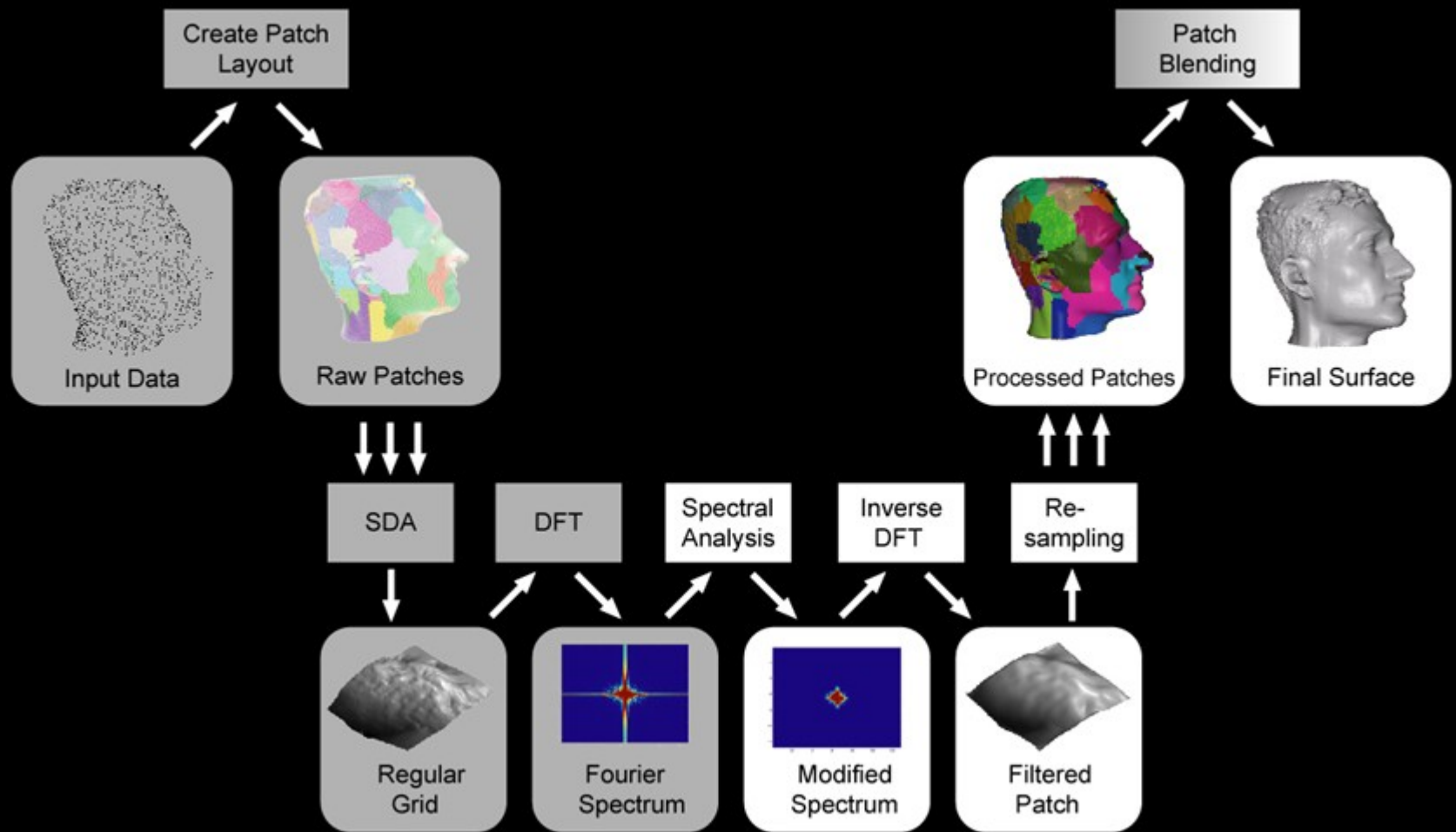

Power Spectrum

Reconstruction

- Filtering can lead to discontinuities at patch boundaries
  - ⇨ Create patch overlap, blend adjacent patches

region of overlap

Sampling rates

↓

Point positions

↓

Normals

↓

Create Patch Layout

Patch Blending

Input Data

Raw Patches

Processed Patches

Final Surface

SDA

DFT

Spectral Analysis

Inverse DFT

Re-sampling

Regular Grid

Fourier Spectrum

Modified Spectrum

Filtered Patch

Surface Restoration

Original
Patch
noise+blur

Gaussian
Filter

Wiener
Filter
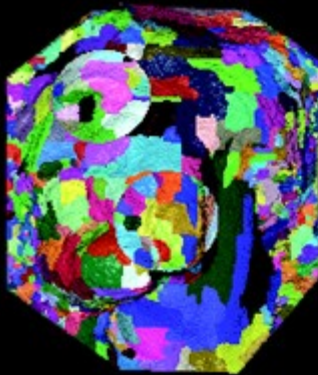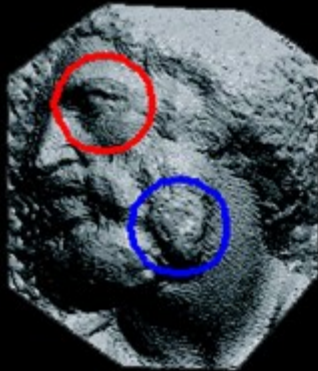
Interactive Filtering

Adaptive Subsampling

4,128,614 pts.
= 100%

287,163 pts.
= 6.9%

Timings

Time

Clustering	9%
Patch Merging	38%
SDA	23%
Analysis	4%
Reconstruction	26%

Timings

#points #patches	460,800 256	3,382,866 595	4,...,614 2,966
Preprocess	10.9	117.2	128.3
Total	15.8	153.0	189.6

Summary

- Versatile spectral decomposition of point-based models

- Effective filtering

- Adaptive resampling

- Efficient processing of large point-sampled models

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Future Work

- Compression

  ⇨ Scalar Representation + Spectral Compression

- Hierarchical Representation

  ⇨ Modeling and Animation

- Feature Detection & Extraction

  ⇨ Robust Computation of Laplacian

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Acknowledgements

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